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TITLE The Structure and Forcing of Teleconnection Patterns Occurring in General Circulation Model Simulations

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THE STRUCTURE AND FORCING OF TELECONNECTION PATTERNS OCCURRING IN GENERAL CIRCULATION MODEL SIMULATIONS

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Several physical mechanisms have been proposed to explain the occurrence of midlatitude atmospheric teleconnection patterns. We consider here two such mechanisms, Rossby wavetrains forced by tropical heating (Hoskins and Karoly, 1981; Simmons, 1982) and the growth of barotropically unstable modes in midlatitudes (Simmons et al., 1983). Because these mechanisms have been discussed in the literature in essentially steady-state form, and because both mechanisms appear capable of explaining the steady-state aspects of observed teleconnection patterns, we consider instead features associated with presumed time-dependent characteristics of these two mechanisms. The two mechanisms appear to have quite different time-dependent characteristics.

We examine several characteristics of teleconnection-pattern fluctuations occurring in GCM simulations in an attempt to discriminate between these two proposed mechanisms. The model used is the NCAR Community Climate Model, whose simulation characteristics are discussed in Pitcher et al. (1983), Ramanathan et al. (1983) and Malone et al. (1984). Five model simulations are considered: a perpetual-January control case with climatological-mean sea-surface temperatures (SST) and four cases in which SST anomalies of various intensities have been introduced in the tropical Pacific. The SST anomaly pattern is that used by Blackmon et al. (1983) in their study of changes in the time-mean state of the atmosphere associated with equatorial Pacific SST anomalies. For brevity, we restrict our attention to the model's Pacific-North American (PNA) teleconnection pattern.

Our findings may be summarized as follows. (1) We find that teleconnection fluctuations with the PNA pattern appear in all five simulations and that the amplitude of the PNA-pattern fluctuations (computed as fluctuations relative to the time-mean of each case individually) is relatively insensitive to changes in the mean tropical SST forcing. (2) Although each SST distribution is fixed in time, the heating rate due to convective processes in the tropical atmosphere can fluctuate. We have tested the hypothesis that tropical heating fluctuations directly force midlatitude geopotential-height fluctuations by performing a cross-spectral analysis of the fluctuations in these two fields, and find no evidence for direct forcing. This is not to be confused with tropical forcing of anomalies in the time-averaged extratropical height field, which Blackmon et al. (1983) have shown does occur in these same simulations. (3) In this same analysis, we did find a highly significant correlation (with a 30-day period) between height fluctuations near 47°N, 165°W and subtropical convective heating to the southeast near 20°N, 135°W; the height fluctuations are in phase with or slightly lead the heating fluctuations. (4) By means of a cross-spectral analysis of height fluctuations at the centers of action (antinodes) of the PNA pattern and at the "nodal" points in between, we conclude that the oscillations linking the Tropical Pacific (TP) and North Pacific (NP) points constitute pure standing oscillations having very high coherence for all periods of 20 days or longer (Figs. 1 and 2). There is no evidence for propagation between these two points. The oscillations connecting the NP and North American (NA) points are of mixed character, appearing as traveling waves at some frequencies and not at others (Fig. 3).

The apparent dependence on geographical position of the character of the oscillation (standing, traveling or indeterminate) is quite puzzling. However similar features can be seen in the complex phase structure of the unstable barotropic normal mode displayed in Fig. 12 of Simmons et al. (1983). In particular, the geopotential height in the tropical central Pacific oscillates out of phase with that in the north Pacific and a distinct node lies between these regions. This mode also has a period of about 50 days, which suggests a possible explanation for the appearance of this period in the simulation analyses.

While the evidence is certainly not conclusive, it suggests that the short term (one to several months) fluctuations in the PNA pattern are associated with the unstable barotropic normal mode. Heating by tropical SST anomalies appears most influential when averages are taken over a season or longer.

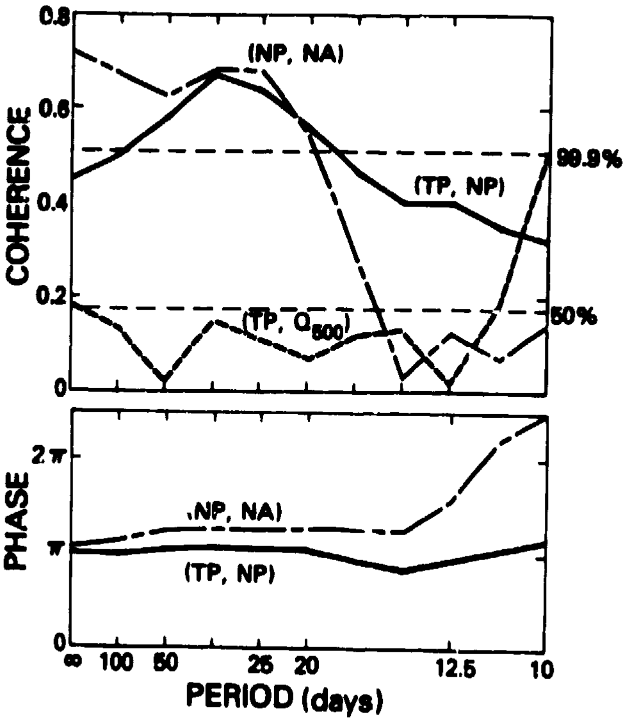

Fig. 1. Coherence and phase from cross-spectral analyses of the 500-mb height fluctuations at TP and NP, at NP and NA, and also at TP with the 500-mb convective heating rate fluctuations in an area directly south of the TP point. Significance levels are indicated on the right side.

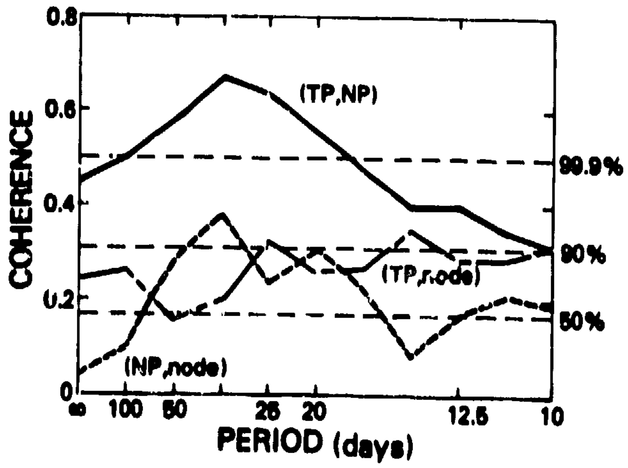

Fig. 2. As in Fig. 1, but for the fluctuations at both TP and NP with those at the intermediate nodal point. The (TP,NP) curve is repeated from Fig. 1.

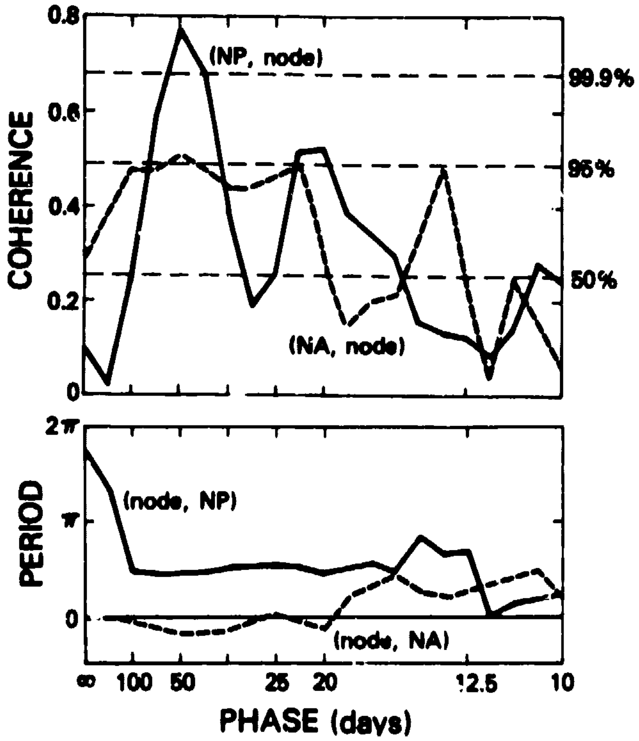

Fig. 3. As in Fig. 1, but for the fluctuations at both NP and NA with those at the intermediate nodal point. Twice as many lags were used in this analysis as were used in Figs. 1 and 2.

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